Automatic Diagnosis for Ailing Rooftop Air Conditioners

The Problem

The rooftop air conditioners (see **Figure 1**) used extensively for small commercial and institutional buildings are often poorly maintained. Faults that are introduced during installation or that develop over time can go undetected for long periods, resulting in high energy costs, shortened equipment life, catastrophic equipment failures, and adverse impacts on occupant comfort and health. Sensors and monitoring equipment can be embedded in the rooftop unit (RTU) controller to detect problems early and alert maintenance personnel. However, until now, technologies for online fault detection and diagnosis (FDD) had been expensive to apply, had not been tested in the field, and had not been able to handle multiple simultaneous faults.

The Solution

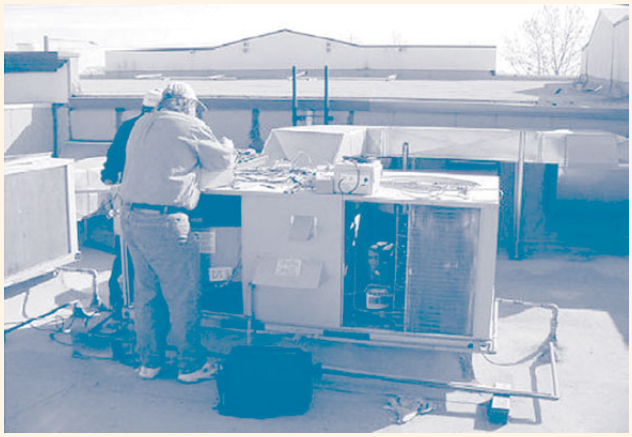
Researchers have now developed a cost-effective, automated FDD technology that is sensitive to early signs of equipment malfunction and able to detect more than one problem at a time. The new system alerts the equipment operator to potential problems and recommends priorities for scheduling maintenance. These capabilities enable FDD systems to cut energy costs; extend equipment life; and help provide a healthy, comfortable environment. With energy and equipment savings, payback can take less than one year. Several products and services incorporating the new features are under development for commercial applications.

Features and Benefits

An FDD system uses sensors embedded in the RTU controller to monitor conditions at various points in the cooling cycle. The system's logic uses data such as ambient drybulb temperature and the dry- and wetbulb temperatures of return, mixed, and supply air to predict normal operating temperatures—including evaporator temperature, suction superheat, condenser temperature, condenser subcooling, and compressor hot gas temperature—as well as differences in condenser and evaporator air temperatures. The FDD system then calculates the difference between monitored and expected temperatures and analyzes the data to determine what problems may be imminent and what actions should be taken. The device communicates this diagnostic information to the facilities manager (see **Table 1**).

Figure 1: Maintaining a rooftop unit

Fault detection and diagnosis (FDD) systems help building operators schedule maintenance when it's needed, resulting in less downtime and lower maintenance costs.



The new FDD system can detect a variety of problems in compressors, heat exchangers, expansion valves, and economizers, and other components. Field tests have shown not only how common these problems are but also how successful an FDD can be at detecting them. Roughly 71 percent—15 of the 21 systems studied—had some kind of problem that affected performance. Filter/drier restrictions plagued 11 of the systems, 10 had a low refrigerant charge, and 8 suffered from both low charge and filter/drier restrictions.

Table 1: Typical FDD results

A fault detection and diagnosis system reports the relative severity of the problems it detects and makes maintenance recommendations. Results shown here are from tests conducted at two modular schools.

	Woodland, California		Oakland, California	
Type of fault	RTU1	RTU2	RTU1	RTU2
Refrigerant charge	Normal	Normal	Normal	**Over-charge**
Liquid-line restriction	**Restriction**	**Severe restriction**	**Restriction**	Normal
Evaporator fouling	Normal	Normal	Normal	**Fouling**
Recommended service	Not yet	Arrange service	Not yet	Arrange service

Table 2: Total lifetime energy cost reductions per RTU for FDD

These estimates show total lifetime net savings for an individual rooftop unit operating in different types of buildings in various California regions. The greater the cooling loads, the greater the possible savings with an FDD system.

Location	Building type	Lifetime net savings ($)[a]
Northern California	Modular school	4,328
	Restaurant	4,800
	Retail store	5,804
Southern California	Modular school	5,496
	Restaurant	6,772
	Retail store	9,756

Note: a. Total savings minus $300 for the cost of the fault detection and diagnosis system.

Researchers estimated the savings potential of FDD systems (see **Table 2**) based on these test results. Annual net savings ranged from about $400 to $1,000, with payback periods of less than one year.

The analysis identified numerous opportunities for cost savings, including:

- Scheduling service when it is needed, instead of doing preventive maintenance on a fixed schedule;
- Achieving energy and peak demand reductions due to more-efficient operation of the equipment;
- Reducing maintenance costs and gaining longer equipment life due to better operation and less run time; and
- Reducing unplanned service interruptions due to equipment failures.

Improvements in RTU performance can also result in improved occupant comfort and health. Though harder to quantify, those benefits may be most important, given the potential impact a malfunctioning system can have on employee performance in an office, on student performance in a school, or on customer retention in a retail outlet.

Applications

FDD systems can be used with RTUs found in a variety of light commercial buildings, such as restaurants and retail stores (including big-box retail facilities). The technology can be used in retrofit applications or be incorporated at the factory in new RTU products.

California Codes and Standards

FDD technology is not currently covered by Title 24. However, the results of this project may lead to including FDD as a prescriptive technology or as a candidate for credits in the 2008 state energy code.

What's Next

Over the next two years, the research team from Purdue University and Field Diagnostic Services Inc. that developed the technology during the first phase will be working on commercialization. They plan to collaborate with engineers at Honeywell on product production and setting up extensive field demonstrations during the final project year. The team intends to monitor FDD devices on a total of 60 air conditioners at 12 buildings.

FDD builds on technology used in the HVAC Service Assistant system that's now available from Honeywell (visit http://acrx.com/serviceassistant.cfm). Enhancements include an online user interface and exclusive use of temperature sensors for diagnostics, which makes installation easier. Honeywell is considering integrating the FDD technology into its more-advanced product offerings.

Collaborators

The organizations involved in this project include Purdue University and Field Diagnostic Services Inc.

For More Information

Reports documenting this project and providing more methodology details may be downloaded from www.energy.ca.gov/reports/2003-11-18_500-03-096-A1.PDF.

Contacts

Field Diagnostic Services, Todd Rossi, 267-583-6330

Purdue University, James Braun, 765-494-9157, jbraun@ecn.purdue.edu

California Energy Commission, Chris Scruton, cscruton@energy.state.ca.us, or visit www.energy.ca.gov/pier/buildings

About PIER

This project was conducted by the California Energy Commission's Public Interest Energy Research (PIER) program. PIER supports public-interest energy research and development that helps improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

Arnold Schwarzenegger, *Governor*

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